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## Distinguishing an Archival Grade Optical Medium

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Presentation to the GIPWoG meeting at the Government Printing Office  
Washington, DC., February 2<sup>nd</sup>, 2006.

*Optical media may only last 3 years according to its detractors... or it may last in excess of 300 years according to some media claims. How does the professional archivist sort through the rhetoric to find data to support the packaging claims?*

*This presentation walks through the methodology prescribed in ISO18927:2002-- the only currently recognized testing standard for recordable optical media lifetime. The results presented have been compiled by Imation to support an archival grade optical product for both 52X CDR and 16X DVD+R with media lifetime determinations exceeding 50 years.*

*US-based Imation Corp (NYSE: IMN) is a leading developer, manufacturer and supplier of magnetic and optical removable data storage media. Additional information about Imation is available on the company's website at [www.imation.com](http://www.imation.com) , or by calling 1-888-466-3456.*

# Recent Activity Re: Archive Optical

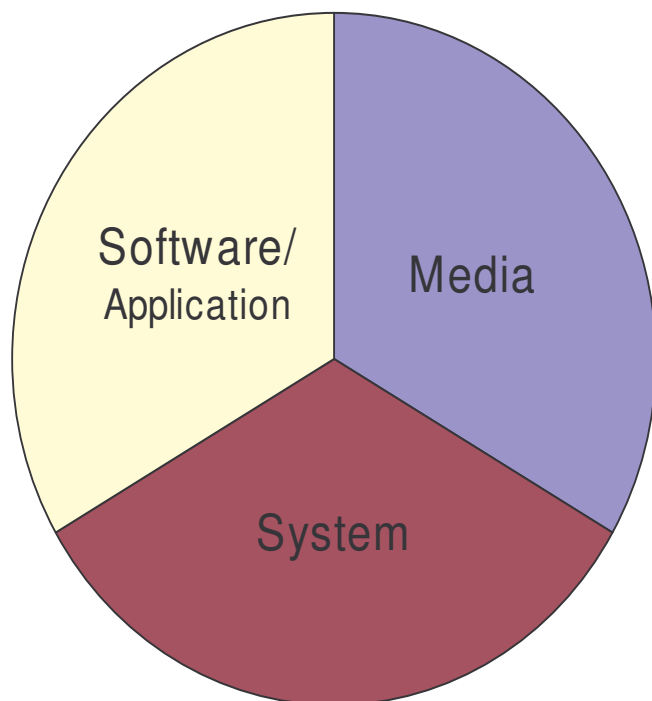
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- Why Optical makes sense for archive, Nick Zihlman, USGS  
OSTA Oct. 18<sup>th</sup>, 2004 <http://www.osta.org/oss/sessions/NZihlman.pdf>
- How Optical Meets Archive and Compliance Requirements, Vivek Navale, NARA  
OSTA Oct. 19<sup>th</sup>, 2004 <http://www.osta.org/oss/sessions/NZihlman.pdf>
- The Search for an Archival Medium - The 100 year Optical Disc, Fred Byers, NIST  
OSTA Oct. 18<sup>th</sup>, 2005 [http://www.osta.org/oss/pdf/presentations05/Byers\\_Presentation.pdf](http://www.osta.org/oss/pdf/presentations05/Byers_Presentation.pdf)
- Life expectancy test for DVD - A shortened alternative, Fred Byers, NIST.  
GIPWoG Oct, 2004, <http://www.itl.nist.gov/div895/gipwog/oct04/Byers%20Oct04.ppt>
- Stability Comparison of Recordable Optical Discs-- A Study of Error Rates in Harsh Conditions,  
Slattery et al, J.of Res. Natl. Inst. Stand Technol., **109**, 517-524 (2004), <http://www.itl.nist.gov/div895/gipwog/StabilityStudy.pdf>
- Optical disks for archiving 12/05/04, Fred Byers, NIST  
OSTA Dec. 5<sup>th</sup>, 2004, <http://www.osta.org/technology/pdf/whitepapers/OSFA-12-05-04.pdf>
- Overview of archival quality media development, Satoshi Wakabayashi, Verbatim  
GIPWoG Mar., 2005, <http://www.itl.nist.gov/div895/gipwog/mar-9-05/VerbatimMar05.ppt>
- DVDA/NIST/GIPWoG Survey on Digital Longevity Report, Oliver Slattery, NIST  
GIPWoG June, 2005, <http://www.itl.nist.gov/div895/gipwog/surveyresults2005.ppt>
- Statistical Analysis of Lifetime distribution for Optical Recordable Disks,  
M.Irie et al, Osaka Sangyo University, ISOM and Optical Data Storage, July 10-14, 2005 (also presented for OSTA/COSA group)
- Report from Imation on research into Archival System, Rusty Rosenburger , Imation  
GIPWoG Oct. 5<sup>th</sup>, 2005, [http://www.itl.nist.gov/div895/gipwog/Oct-5-05/Rosenburger\\_3reports.pdf](http://www.itl.nist.gov/div895/gipwog/Oct-5-05/Rosenburger_3reports.pdf)
- Measurements for predicting Life Expectancies of Higher Density Magnetic and Optical  
Media, Vivek Navale, NARA 10/21/05 Presentation at the INSIC-NIST Workshop, Boulder, Co.

# Archive Generalities



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To state the obvious...

- Any solution requires longevity for Media, Hardware and the Software/Application to reconstruct  
⇒ Media life is a necessary but insufficient condition to assure data recovery
- Any media may experience premature failure because of improper handling and/or storage conditions

(see NIST Special Publication 500-252  
*Information Technology: Care and Handling for the Preservation of CDs and DVDs*)

# Options for the removable media piece



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*Imation sells both...*

## Magnetic Tape:

SDLT/DLT, LTOX, 9X40, 34XX,  
3590 ... 40-800G/cart, \$50-80/cart,  
data center environment

### Typical Failure Mechanisms:

edge damage (dropped or  
mishandled), magnetic remnance  
decay, binder decomposition, ...

### Standardized Test Method:

no adopted standard. The most  
current studies seem to indicate  
magnetic remnance decay as the  
“weakest link”. Typical Lifetime  
Estimates range from 30-100 years  
when based solely on magnetic  
remnance decay.

## Optical Disk:

CD-R, DVD +/-R, RW, ... 0.65-5  
G/disk, < \$2 disk, PC office  
environment

### Typical Failure Mechanisms:

handling scratches, surface debris,  
delamination, prolonged UV/sunlight,  
dye/reflector decomp./corrosion, ...

### Standardized Test Method:

ISO 18927 is the only adopted  
recordable media standard (CDR).  
NIST has recently (12/5/05) proposed  
amendments to ISO incorporating  
DVD+/-R. Media Lifetime Estimates  
ranging from 3-300 years are largely  
unsupported by published data.

# Not all Disks are Created Equal !

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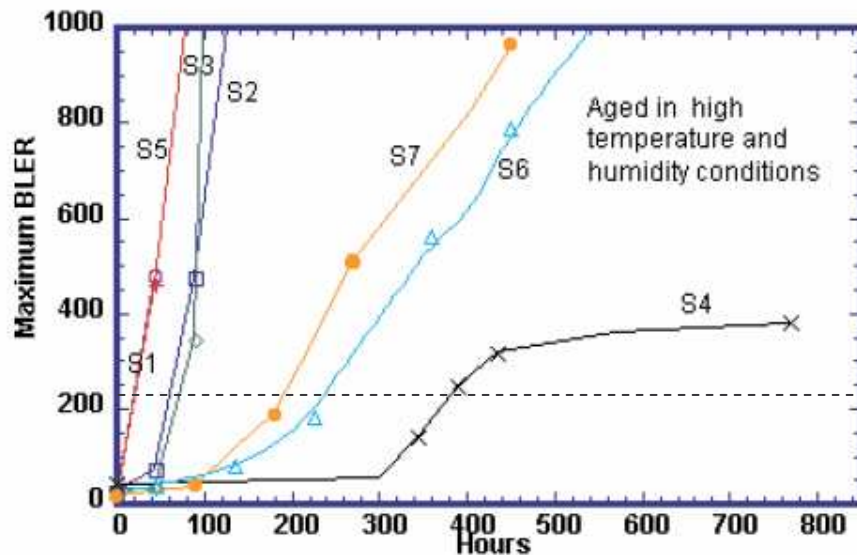


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The commoditization of optical media products has generally forced manufacturers to cut cost out of materials, process, testing, etc at the expense of quality.

- As a result, some disks fail within 3-5 years even if handled and stored properly. *For many applications, this is completely acceptable at a “throw away” price of ~ 50¢ per 5GB DVD disk .*
- Worse yet, some disks are so poorly made or record so poorly that they “fail” right out of the box. *This is a blemish that the optical industry is working to address.*
- Some applications justify careful handling, suitable storage and long lasting media. Archival media life claims need to be substantiated by a thorough testing regimen of the specific product construction materials and manufacturing processes. *If you need “Archive grade” rather than “Standard grade” media, ask to see the life test results.*

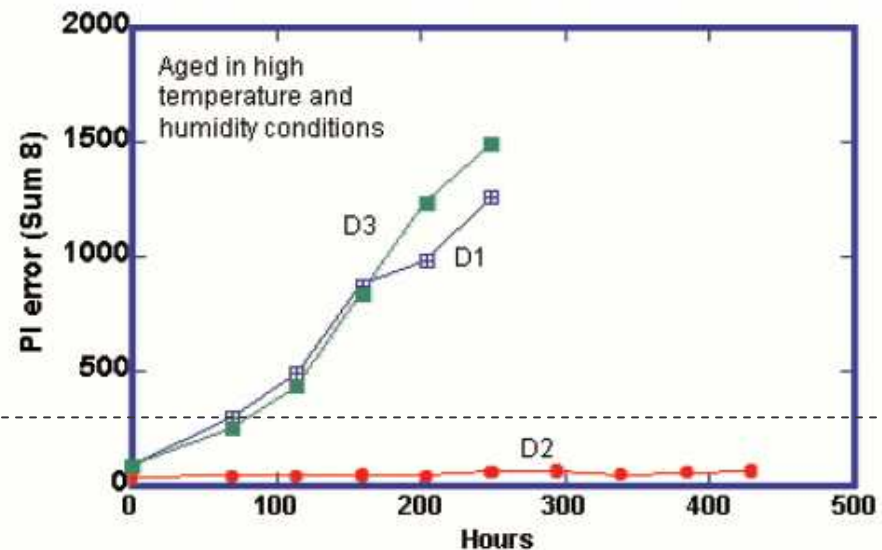
# Figures from 2004 NIST Stability Comparison



DVD-R  
PIEsum8= 280

What disk is your data on?

CD-R  
BLER<sub>max</sub> = 220/sec



Slattery et al, J.of Res. Natl. Inst. Stand Technol., **109**, 517-524 (2004), <http://www.itl.nist.gov/div895/gipwog/StabilityStudy.pdf>

# Background from last GIPWoG meeting...

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## **Conclusions compiled from 3 market survey/studies :**

- No broad-based market opportunity identified outside certain Government agencies for “special” archival optical system- development with Philips put on hold.
- Users generally satisfied with current archiving solutions
- Hardware and software archiving strategies bigger concern than media life expectancy
- Magnetic tape perceived as more stable long-term solution than optical disk
- Lack of a Standard and Certification method is a key factor in preventing the widespread adoption of optical; NIST is working with industry leaders (Through OSTA/ODATS committee) to define new test and reliability methods.

## **Imation’s “Certified” Archival media approach :**

- Imation is developing CD/DVD compatible media with special features designed for long-term archiving and testing (ISO 18927) projecting 50+ years media life
- Imation collaborating with NIST on media life prediction assurance with ultimate objective of “NIST seal-of -approval” worthiness.

Report from Imation on research into Archival System (Rusty Rosenburger / Imation, Oct. 5<sup>th</sup>, 2005)  
[http://www.itl.nist.gov/div895/gipwog/Oct-5-05/Rosenburger\\_3reports.pdf](http://www.itl.nist.gov/div895/gipwog/Oct-5-05/Rosenburger_3reports.pdf)



# Imation Archive Grade Optical Disk

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## The Original Goal ...

- Define 52X CD-R, 16X DVD+R compatible products for archive applications with a goal of 50 year average media lifetime verifiable by ISO18927.
- Commenced testing with disks using “best” dye/reflector candidate and most robust format<sup>1</sup> (+R) based on preliminary screening tests
- Imation proprietary ForceField<sup>TM</sup> protection coating<sup>2</sup> (anti-scratch, anti-static, anti-fingerprint) to prevent most user handling errors from causing fatal errors.

1. <http://www.cdfreaks.com/print/article/113>

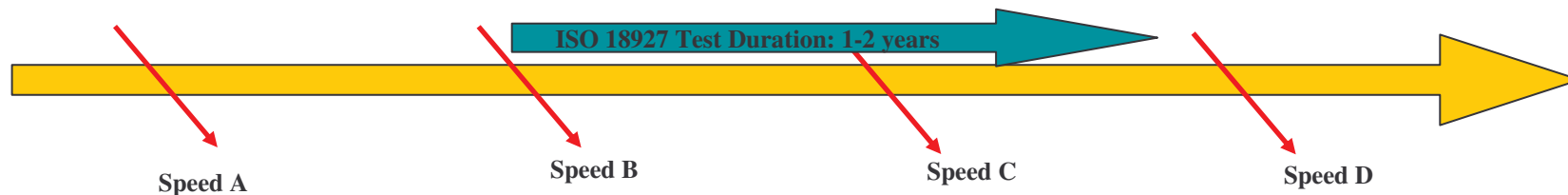
2. [http://www.imation.com/products/pdfs/ForceField\\_White\\_Paper.pdf](http://www.imation.com/products/pdfs/ForceField_White_Paper.pdf)



## Time Required for ISO18927

*Fred Byers (NIST preservation working group) asked why the optical media companies haven't typically been following their own testing protocol (namely ISO18927) for lifetime estimations.*

*One answer is that the test requires a lot of work with no clear business incentive. Another answer pertains to the length of time that the ISO18927 test takes (1-2 years) in relation to material and process changes occurring with media speed migrations (1 year typical).*



*With CD/DVD media now at terminal recording speeds (52X and 16X respectively), material and process changes needn't obviate extensive lifetime testing results.*

# ISO18927 Lifetime Testing Checklist

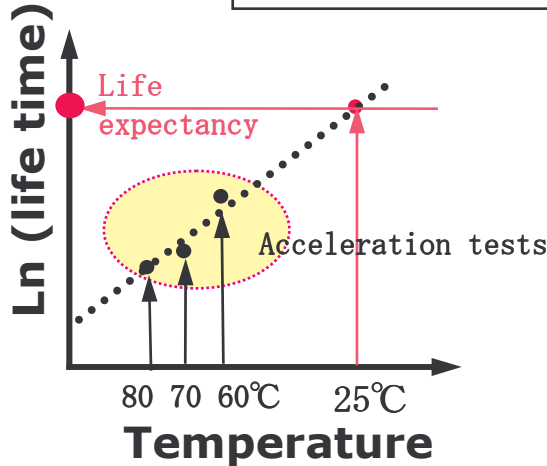
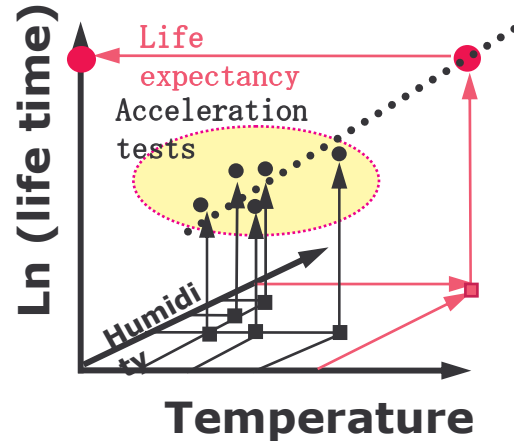
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- 1. Record groups of media samples ( $N > 10$ ) for each of (at least) 5 environmental stress conditions outlined in user defined test plan.**
- 2. Measure initial error rate across media surface ( $BLER_{max}$  for CD-R,  $PIE_{sum8}$  for DVD+/-R).**
- 3. For each environmental cycle, expose media groups to environmental stress conditions for the planned time increment and remeasure disk error rates.**
- 4. Plot disk error rates vs. stress time and determine sample failure ( $BLER_{max} > 220/sec$  for CD-R,  $PIE_{sum8} > 280$  for DVD+/-R).**
- 5. Verify that 5 stress conditions exhibit the same failure mechanism by plotting ranked failure on Lognormal plot for ( $N > 10$ ) samples in all 5 groups**
- 6. Determine Eyring model fitting parameters and acceleration factors for each stress condition. Compile all data from 5 conditions multiplied by acceleration factors to confirm agreement of all conditions. Calculate Lifetime Estimate and confidence interval.**

# The Eyring model requirement for ISO 18927:

	Arrhenius model	Eyring model
Stress	Temperature only	Temperature & Humidity
Equation	$t = D_0 \exp\left(\frac{E_s}{kT}\right)$	$t = A T^d \cdot \exp\left(\frac{E_s}{kT}\right) \cdot \exp\left\{R\left(B - \frac{C}{T}\right)\right\}$
	<p>t=life time, T=Temperature, R=Relative humidity [%],  Es=activation energy , k=Boltzmann's constant  D,k,A,B,C=constants</p>	
	 $\ln t_1 - \ln t_2 = \frac{E_s}{k} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$	 $\ln(t_{50\%}) = \ln(A) + \left(\frac{E_s}{k}\right) \times T^{-1} + B \times R$

Statistical Analysis of Lifetime distribution for Optical Recordable Disks, M.Irie et al, Osaka Sangyo University, ISOM and Optical Data Storage, July 10-14, 2005

Optical Product Differentiation

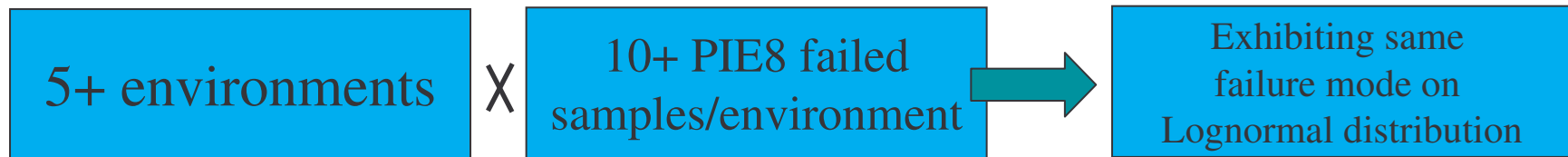
2/2/2006 GIPWoG Meeting, Government Printing Office

Jathan Edwards

# ISO 18927 test plan applied to 16X DVD+R



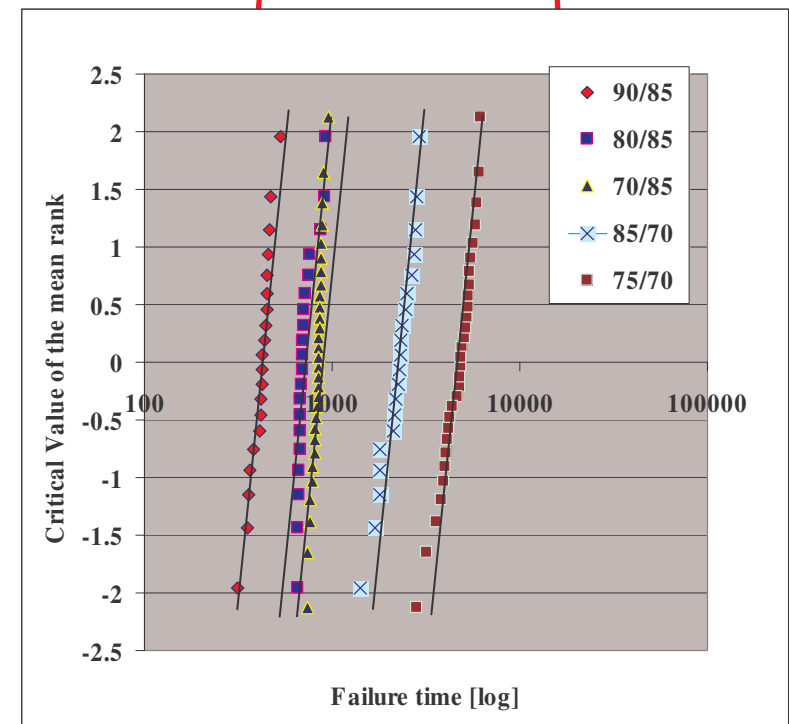
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## 16X DVD+R test plan (started 3/05)

(Initial recording quality PIE8 < 20% spec limit of 280)

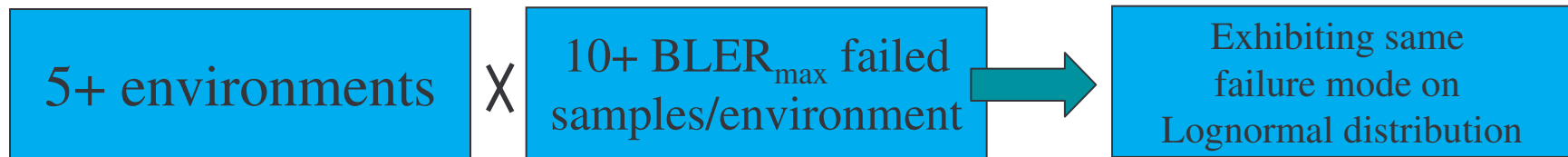
Temp [°C]	RH [%]	# Disks	Test Increment
65	55	60	500 hrs
70 ✓	85	30	250
75 ✓	70	30	250
80	55	20	250
80 ✓	85	20	250
85 ✓	70	20	250
90 ✓	85	20	150



# ISO 18927 test plan applied to 52X CD-R



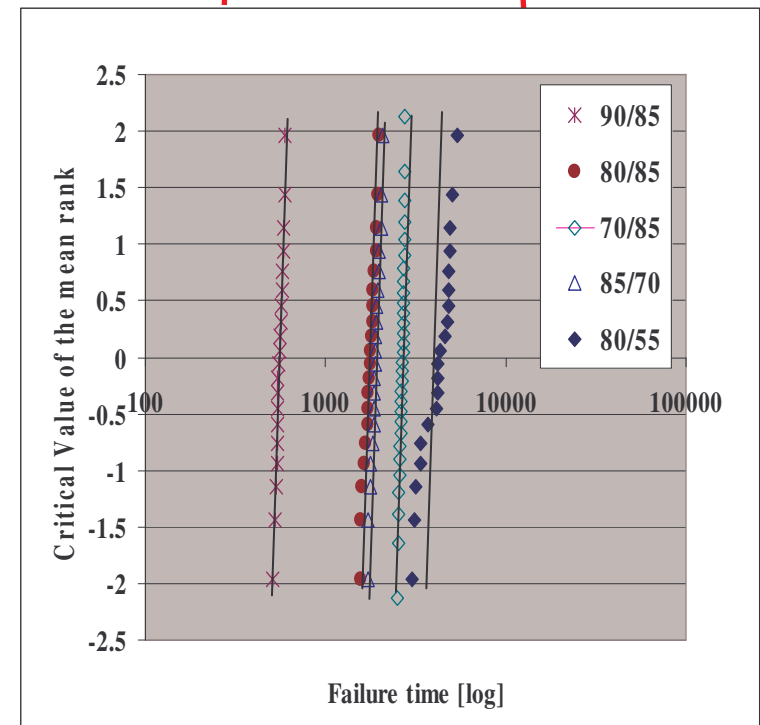
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## 52X CD-R test plan (started 3/05)

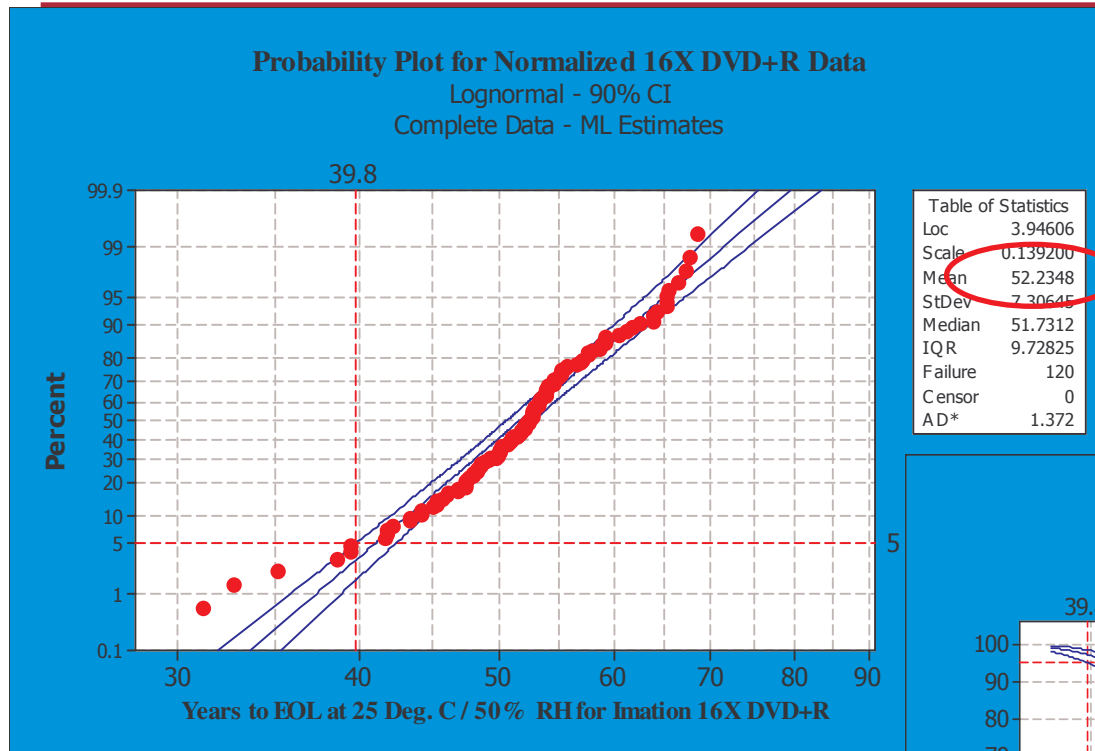
(Initial recording quality BLER < 20% spec limit of 220/sec)

Temp [°C]	RH [%]	# Disks	Test Increment
65	55	60	500 hrs
70 ✓	85	30	250
75	70	30	250
80	55	20	250
80 ✓	85	20	250
85 ✓	70	20	250
90 ✓	85	20	150



# 16X DVD+R data analysis with full 5 conditions

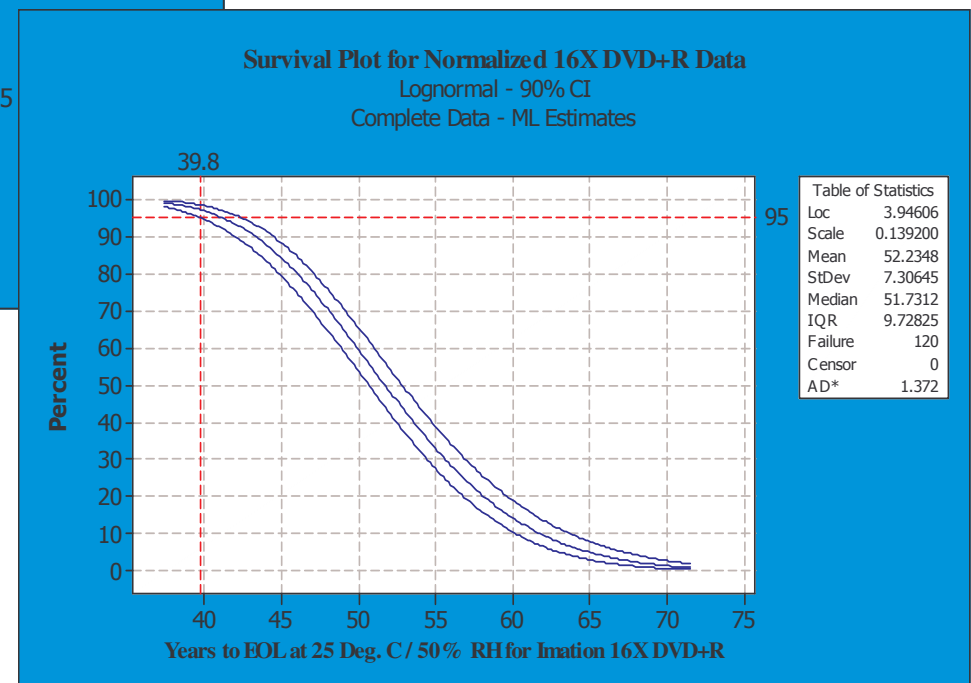
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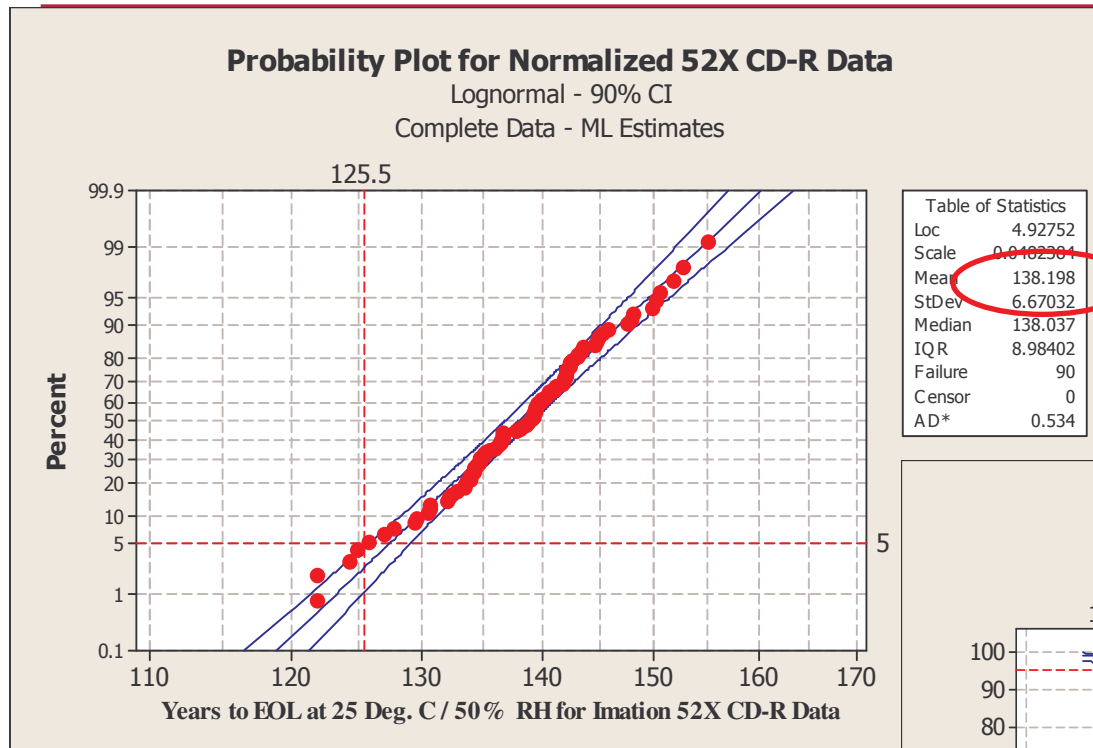
Estimated average  
lifetime = 52 years

Lifetime Estimates depend on the  
required survivor probability

Acknowledgment to Dr. William Murray, independent consultant, for providing expert review of lifetime data analysis. Statistical calculations done using Minitab.



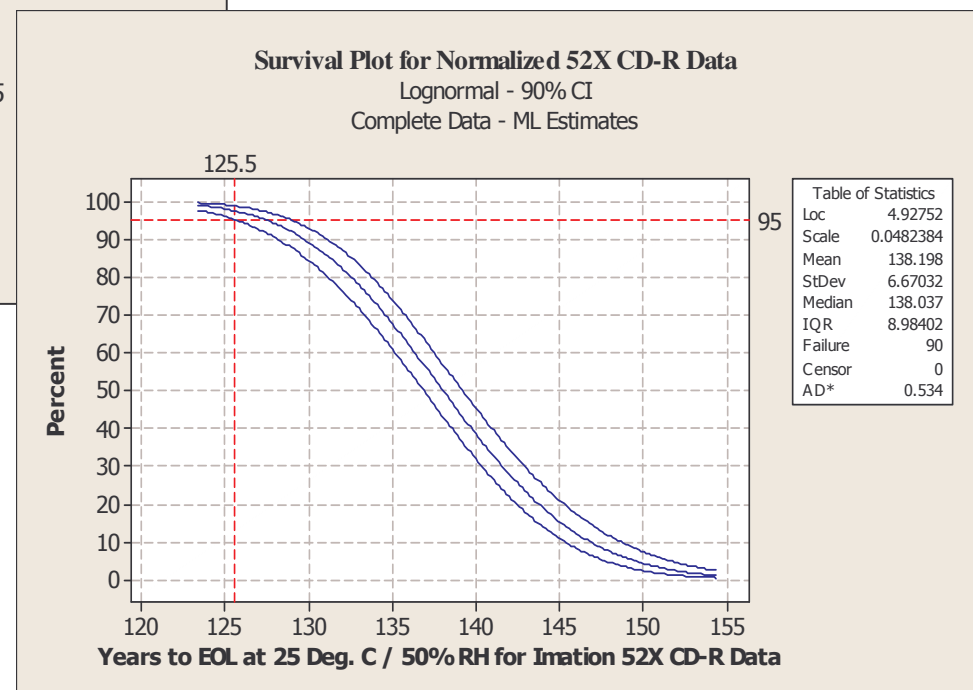
# 52X CD-R data analysis with 4 of 5 conditions



Estimated average  
lifetime = 138 years

Lifetime Estimates depend on the  
required survivor probability

Acknowledgment to Dr. William Murray, independent consultant, for providing expert review of lifetime data analysis. Statistical calculations done using Minitab.





# The Life Expectancy Statement

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*At a storage condition of 25°C (77°F) and 50% RH, 95% of the DVD+R product evaluated will last a minimum of 39.8 years and 95% of the CD-R product evaluated will last a minimum of 125.5 years, with 95% confidence, considering only the effects of temperature and humidity. Likewise, at these storage conditions, > 50% of both products evaluated will last a minimum of 50 years, with 95% confidence considering only the effects of temperature and humidity. Disks exposed to more severe conditions of temperature and humidity are expected to experience a shorter life.*

*The test plan documented in ISO18927 does not attempt to model degradation due to exposure to light, corrosive gases, contaminants, handling, improper storage or variations in the quality of the recording/playback system.*



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# Imation Archive Grade Optical Disk

## The Original Goal ...

- Define 52X CD-R, 16X DVD+R compatible products for archive applications with a goal of 50 year average media lifetime.
- Commenced testing with disks using “best” dye/reflector candidate and most robust format (+R) based on preliminary screening tests
- Imation proprietary ForceField™ protection coating (anti-scratch, anti-static, anti-print) to prevent most user handling errors.

## The Status...

- 50+ year average lifetime estimate verifiable by ISO18927 data package.
- Ready to test market 52X CD-R, 16X DVD+R compatible products from verified process and material set. These products are not currently commercially available.
- Initiating customer interviews in the government segment to gain feedback for optional features (printable surfaces, storage casing,...)
- Ongoing work with OSTA/ODATS & NIST to develop new testing and reliability methods

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***Thank you!  
Questions?***